Influence of the HiPIMS voltage on the time resolved platinum ions energy distributions

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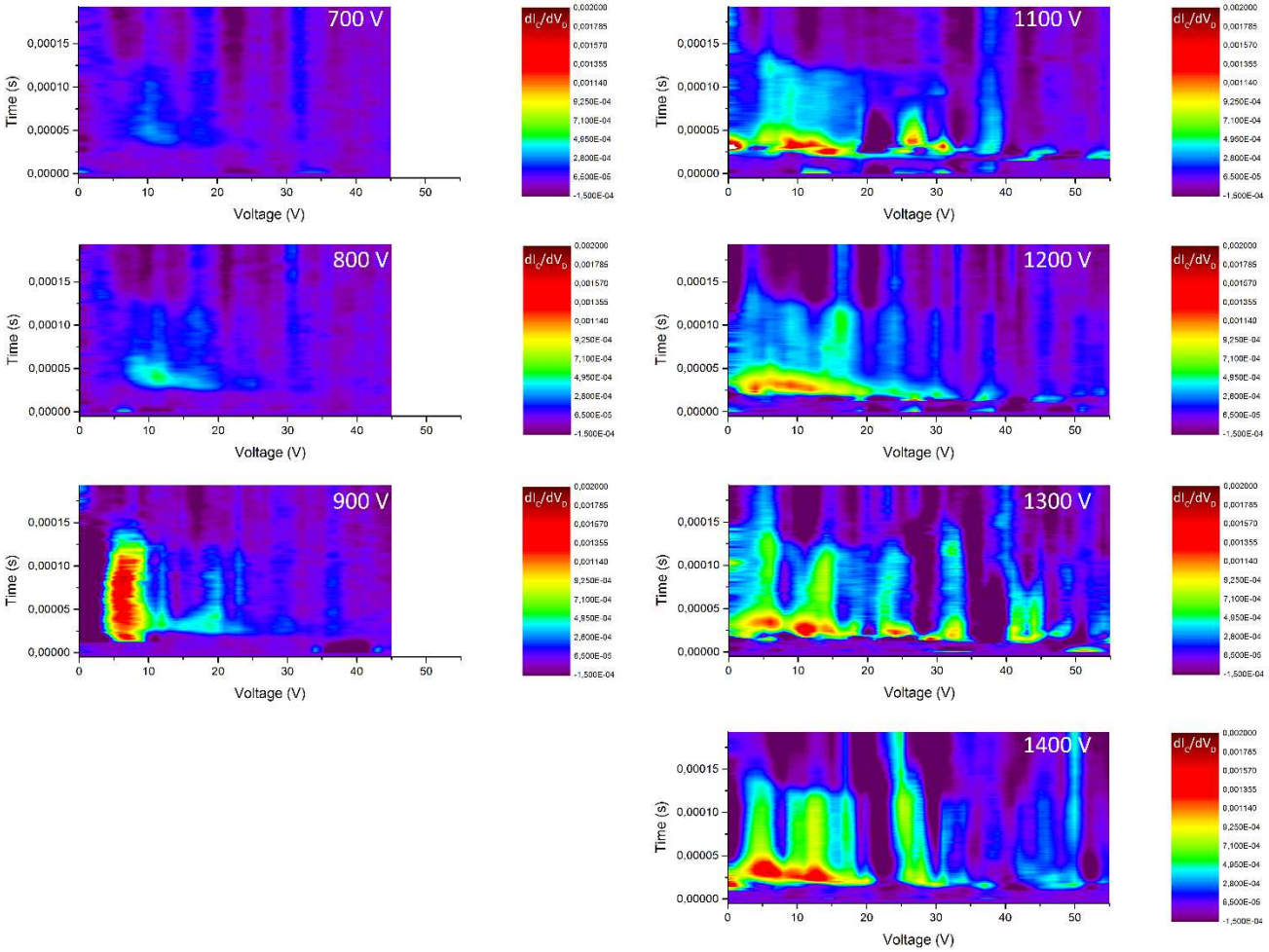

Fig. 1. Evolution of the time resolved platinum ions energy distributions for different HiPIMS voltages (700 V to 1400 V). The energy is expressed in function of the RFEA's discriminator voltage. The HiPIMS voltage values are shown at the top of each figure. Same intensity color code is used for each figure.

***Abstract* – High Power Impulse magnetron sputtering (HiPIMS) is a common way to create a high and dense ionized metallic vapor without the use of an alternative ionizing device, like radio frequency loops. HiPIMS has been used to perform the deposition of platinum thin films in order to control their morphology. This feature known to depend on the energy of the Pt species incoming onto the substrate during the deposition has to be carefully studied. Therefore, it's necessary to study the ions energy distribution during the sputtering pulse and to follow its evolution with the HiPIMS regime. Pictures of this evolution are presented.**

High Power Impulse Magnetron sputtering (HiPIMS) sources tend to be used in industrial physical vapor deposition processes which require high reliability for thin layer deposition. HiPIMS produces a dense ionized metallic vapor, which is not the case with pulsed Direct Current Magnetron Sputtering (DCMS). Some authors report that the ions could reach 90 % of the sputtered vapor [1]. This value obviously depends on numerous experimental parameters.

Here, the sputtered 2" target is made of pure Pt (99.99%). Retarded Field Energy Analyzer (RFEA) is placed at the sample holder exact position. The RFEA is composed of five stainless steel grids (earth, repeller, discriminator, suppressor,

collector) composed of 100 µm diameter holes and spaced by 300 µm thick insulators. The diameter of the opening hole placed in front of the race track is 14 mm. RFEA is a very suitable device to measure the ions energy distribution function (IEDF) and then contribute to a better understanding of the process. The study focuses on the time evolution of the IEDF as a function of the voltage applied on the cathode. Although several works have already been done on the IEDF in HiPIMS processes with mass spectroscopy [2] or with a time resolved RFEA [3], studies of the time resolved IEDF using a RFEA has never been carried out to our knowledge in the case of noble metals like platinum.

The HiPIMS power source is a Hüttinger TPHS 4002 which is connected to an unbalanced 2" magnetron placed in a vacuum chamber. The argon pressure is fixed to 1 Pa and the distance between the HiPIMS cathode and the grounded first RFEA grid is fixed to 50 mm. The RFEA is placed in front of the target race track. The HiPIMS voltage is negatively tuned between 700 V and 1400 V with an increased step of 100 V. The impulse power starts at t = 0 s and stops 100 µs later, with an impulse frequency of 50 Hz.

The figure shows 7 pictures corresponding to the time resolved IEDF deduced from the RFEA measurements. These distributions are obtained by the derivation of the current I_c in function of the discriminator grid voltage V_D. To increase the signal to noise ratio without distorting the raw measurements, smoothing by the Savitzky-Golaya method (span of 9, polynomial of degree 3) was performed on the measured current versus the time and versus the energy. Each picture corresponds to a fixed HiPIMS voltage. For HiPIMS voltage below 1000 V, the discriminator grid voltage is tuned between 0 V and 50 V and between 0 V and 60 V for the other cases, with a voltage step of 1 V. The IEDF are recorded over 200 µs, with a start 5 µs before the HiPIMS impulse at t = 0 s. The 1000 V HiPIMS case is not presented here. The same rainbow color's palette is used in each case in order to reveal the differences between all distributions in term of intensity. Because of the high cost of Pt, we chose to acquire only five IVDF for a given voltage pulse. Such experiment allows us to have sensitivity close to 2 orders of magnitude. Below an intensity of $5\ 10^{-5}$, we consider that the signal-to-noise ratio is to poor. The area of the contour graph in dark blue and purple are considered as background. Several important observations can be made based on the time-resolved results presented in the figure.

(1) For each voltage, the first ions do not reach the collector grid at t=0. The arrival time decreases with the voltage increase and tends towards 20 µs.

(2) On the 8 images, the IEDF are not monotonous and display several peaks showing that several energy groups of ions (metallic, gas) reach the detector.

(3) Several peaks are clearly visible between 0 and 37 eV. Their maximum intensities are in range of about $5\ 10^{-4}$ – $15\ 10^{-4}$ dI_c/dV_d (green, yellow, orange and red). After 37 eV, clear identification of peak is questionable (intensity below $5\ 10^{-5}$, blue and purple). For -1300 V, an unexplained peak appears between 40 and 45 eV.

(4) For -1200 V and -1400 V and for 25 µs<T<50µs, a unique large peak is observed which extends from 3 to 15 eV. This peak trends to be gradually separated as a function of time (as observed in [2]) after 50 µs.

(5) When the HiPIMS voltage increases, the ionization processes favor the appearance of poly-energetic peaks rather than a simple increase of the current intensity of a single mono-energetic beam. The number of these peaks of the distribution increases with the voltage rise.

(6) For increasing voltages, the populations in different energy groups are similar to each other, which mean that the ions are well distributed on these energy groups, and that high energy ions appear for high voltage.

In conclusion, pictures displaying time resolved platinum IEDF at various HiPIMS voltages have been presented. They exhibit several well defined energy groups of species ranging from 5 eV to 50 eV. The number of these groups and their respective population seem to depend on the voltage applied to the magnetron. Since these results have been obtained with a home-made diagnostic being developed, they should be completed by further measurements, or by using complementary techniques such as mass spectroscopy to determine the metal and the gas contributions to the these distributions. Preliminary obtained data confirmed the presence of energy groups of Ar and Pt ions.

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